

CLAIMS

What is claimed is:

1. A method of filtering noise from a mixed sound signal to obtain a filtered target signal,
5 comprising the steps of:
inputting the mixed signal through a pair of microphones into a first channel and a second
channel;
separately Fourier transforming each said mixed signal into the frequency domain;
computing a signal short-time spectral amplitude $|\hat{S}|$ from said transformed signals;
computing a signal short-time spectral complex exponential $e^{i \arg(S)}$ from said transformed
signals, where $\arg(S)$ is the phase of the target signal in the frequency domain;
computing said target signal S in the frequency domain from said spectral amplitude and
said complex exponential.

15 2. The method of claim 1 wherein said target signal S in the frequency domain is inverse
Fourier transformed to produce a filtered target signal s in the time domain.

3. The method of claim 1 further comprising the step of computing a spectral power matrix
and using said spectral power matrix to compute said spectral amplitude and said spectral
20 complex exponential.

4. The method of claim 3 wherein said spectral power matrix is computed by spectral
channel subtraction.

5. The method of claim 3 wherein said signal short-time spectral amplitude is computed by the estimation equation

$$|\hat{S}| = \mathbf{E}[|S| | X_1, X_2] = \frac{\sqrt{\pi}}{2} \frac{1}{\sqrt{C_1}} \exp\left(-\frac{C_2^2}{8C_1}\right) \left[1 + \frac{C_2^2}{4C_1} I_0\left(\frac{C_2^2}{8C_1}\right) + \frac{C_2^2}{4C_1} I_1\left(\frac{C_2^2}{8C_1}\right) \right]$$

5 where $I_0(z) = \frac{1}{2\pi} \int_0^{2\pi} \exp(z \cos \beta) d\beta$, $I_n(1) = \frac{1}{2\pi} \int_0^{2\pi} \cos(\beta) \exp(z \cos \beta) d\beta$,

$$C_1 = \frac{1}{\rho_s} + \frac{1}{\det R_n} (R_{22} + R_{11}|K|^2 - KR_{12} - \bar{K}R_{21}), \quad C_2 = \frac{2}{\det R_n} |\bar{X}_1 R_{22} + \bar{X}_2 KR_{11} - X_2 R_{12} - X_1 \bar{K}R_{21}|,$$

X_1 and X_2 are the Fourier transformed first and second signals respectively, R_{nm} are elements of said spectral power matrix, and K is a constant.

6. The method of claim 3 wherein said signal short-time spectral complex exponential is computed by the estimation equation

$$z \equiv e^{i\arg(S)} = \frac{R_{22}X_1 + R_{11}\bar{K}X_2 - R_{21}\bar{K}X_1 - R_{12}X_2}{|R_{22}X_1 + R_{11}\bar{K}X_2 - R_{21}\bar{K}X_1 - R_{12}X_2|}$$

7. The method of claim 3 wherein said signal short-time spectral complex exponential is 15 computed by the estimation equation

$$z \equiv e^{i\arg(S)} = \frac{R_{22}X_1 + R_{11}\bar{K}X_2 - R_{21}\bar{K}X_1 - R_{12}X_2}{|R_{22}X_1 + R_{11}\bar{K}X_2 - R_{21}\bar{K}X_1 - R_{12}X_2|}$$

8. The method of claim 7 wherein said target signal S in the frequency domain is computed by the equation

$$S = zA$$

9. The method of claim 1 wherein said target signal is computed by multiplying said signal short-time spectral amplitude by said signal short-time spectral complex exponential.

5 10 The method of claim 1 further comprising the step of calibrating a function $K(\omega)$, said function equal to a ratio of one said Fourier transformed signal to the other, by the estimation equation

$$K(\omega) = \frac{\sum_{t=1}^F X_2^c(t, \omega) \overline{X_1^c(t, \omega)}}{\sum_{t=1}^F |X_1^c(t, \omega)|^2}$$

where $X_1^c(t, \omega), X_2^c(t, \omega)$ represents the discrete windowed Fourier transform at frequency ω , and time-frame index t of the transformed signals x_1^c, x_2^c within time frame c .

11 An apparatus for filtering noise from a mixed sound signal to obtain a filtered target signal, comprising:

a pair of input channels for receiving mixed signals from a pair of microphones;

15 a pair of Fourier transformers, each receiving a mixed signal from one of said channels and Fourier transforming said mixed signal into a transformed signal in the frequency domain;

a filter, said filter receiving said transformed signals and computing a signal short-time spectral amplitude $|\hat{S}|$ and a signal short-time spectral complex exponential $e^{i \arg(S)}$ from said transformed signals, where $\arg(S)$ is the phase of the target signal in the frequency domain; and

20 Wherein said filter computes said target signal S in the frequency domain from said spectral amplitude and said complex exponential.

12. The apparatus of claim 11 further comprising a spectral power matrix updater, said updater receiving said transformed signals and computing therefrom a spectral power matrix, and outputting said spectral power matrix to said filter.

5 13. The apparatus of claim 11 further comprising an inverse Fourier transformer receiving said target signal S in the frequency domain and inverse Fourier transforming said target signal into a filtered target signal s in the time domain.

10 14. A program storage device readable by machine, tangibly embodying a program of instructions executable by machine to perform method steps for filtering noise from a mixed sound signal to obtain a filtered target signal, said method steps comprising:

inputting the mixed signal through a pair of microphones into a first channel and a second channel;

separately Fourier transforming each said mixed signal into the frequency domain;

computing a signal short-time spectral amplitude $|\hat{S}|$ from said transformed signals;

computing a signal short-time spectral complex exponential $e^{i \arg(S)}$ from said transformed signals, where $\arg(S)$ is the phase of the target signal in the frequency domain;

computing said target signal S in the frequency domain from said spectral amplitude and said complex exponential.

20 15. The device of claim 14 wherein said target signal S in the frequency domain is inverse Fourier transformed to produce a filtered target signal s in the time domain.

16. The device of claim 14 further comprising the step of computing a spectral power matrix and using said spectral power matrix to compute said spectral amplitude and said spectral complex exponential.

5 17. The device of claim 16 wherein said spectral power matrix is computed by spectral channel subtraction.

18. The device of claim 16 wherein said signal short-time spectral amplitude is computed by the estimation equation

$$|\hat{S}| = \mathbb{E}[|S| | X_1, X_2] = \frac{\sqrt{\pi}}{2} \frac{1}{\sqrt{C_1}} \exp\left(-\frac{C_2^2}{8C_1}\right) \left[1 + \frac{C_2^2}{4C_1} I_0\left(\frac{C_2^2}{8C_1}\right) + \frac{C_2^2}{4C_1} I_1\left(\frac{C_2^2}{8C_1}\right) \right]$$

where $I_0(z) = \frac{1}{2\pi} \int_0^{2\pi} \exp(z \cos \beta) d\beta$, $I_n(1) = \frac{1}{2\pi} \int_0^{2\pi} \cos(\beta) \exp(z \cos \beta) d\beta$,

$$C_1 = \frac{1}{\rho_s} + \frac{1}{\det R_n} (R_{22} + R_{11}|K|^2 - KR_{12} - \bar{K}R_{21}), \quad C_2 = \frac{2}{\det R_n} |\bar{X}_1 R_{22} + \bar{X}_2 KR_{11} - X_2 R_{12} - X_1 \bar{K}R_{21}|,$$

X_1 and X_2 are the Fourier transformed first and second signals respectively, R_{nm} are elements of said spectral power matrix, and K is a constant.

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19. The device of claim 16 wherein said signal short-time spectral complex exponential is computed by the estimation equation

$$z \equiv e^{i \arg(S)} = \frac{R_{22}X_1 + R_{11}\bar{K}X_2 - R_{21}\bar{K}X_1 - R_{12}X_2}{|R_{22}X_1 + R_{11}\bar{K}X_2 - R_{21}\bar{K}X_1 - R_{12}X_2|}$$

20 20. The device of claim 16 wherein said signal short-time spectral complex exponential is computed by the estimation equation

$$z \equiv e^{i\arg(S)} = \frac{R_{22}X_1 + R_{11}\bar{K}X_2 - R_{21}\bar{K}X_1 - R_{12}X_2}{|R_{22}X_1 + R_{11}\bar{K}X_2 - R_{21}\bar{K}X_1 - R_{12}X_2|}$$

21. The device of claim 20 wherein said target signal S in the frequency domain is computed by the equation

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$$S = zA$$

22. The device of claim 14 wherein said target signal is computed by multiplying said signal short-time spectral amplitude by said signal short-time spectral complex exponential.

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23. The device of claim 14 further comprising the step of calibrating a function $K(\omega)$, said function equal to a ratio of one said Fourier transformed signal to the other, by the estimation equation

$$K(\omega) = \frac{\sum_{t=1}^F X_2^c(l, \omega) \overline{X_1^c(l, \omega)}}{\sum_{t=1}^F |X_1^c(l, \omega)|^2}$$

15 where $X_1^c(l, \omega), X_2^c(l, \omega)$ represents the discrete windowed Fourier transform at frequency ω , and time-frame index l of the transformed signals x_1^c, x_2^c within time frame c .

24. The device of claim 14 further comprising the step of updating a function $K(\omega)$, said function equal to a ratio of one said Fourier transformed signal to the other, said updating effected by using a linear combination between a previous value for $K(\omega)$ at a time $t-1$ and a 20 current value for $K(\omega)$ at a time t according to the equation

$$K^t(\omega) = (1 - \alpha)K^{t-1}(\omega) + \alpha K(\omega)$$

where α is an adaptation rate.

ABSTRACT OF THE INVENTION

Disclosed is an apparatus for and a method of filtering noise from a mixed sound signal to obtain a filtered target signal, comprising the steps of inputting the mixed signal through a pair of microphones into a first channel and a second channel, separately Fourier transforming each said mixed signal into the frequency domain, computing a signal short-time spectral amplitude $|\hat{S}|$ from said transformed signals, computing a signal short-time spectral complex exponential $e^{i \arg(S)}$ from said transformed signals, where $\arg(S)$ is the phase of the target signal in the frequency domain, computing said target signal S in the frequency domain from said spectral amplitude and said complex exponential.

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